

KVL \Rightarrow

$$V_a(t) - E_b(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} \quad (1)$$

$$E_b(t) = k_b \omega(t) \quad (2)$$

$$J \dot{\omega}(t) + B \omega(t) = T(t) \quad (3)$$

$$T(t) = k_t i_a(t) \quad (4)$$

$$\omega(t) = \dot{\theta}(t) \quad (5)$$

R_a = Armature resist.

L_a = Armature induct.

J = Load inertia

B = friction constant

$i_a(t)$ = armature current

$V_a(t)$ = armature voltage

ω = rotation speed

θ = angular displacement

T = rotor torque

k_t = torque constant

k_b = back emf constant

E_b = Back emf voltage

S-domain

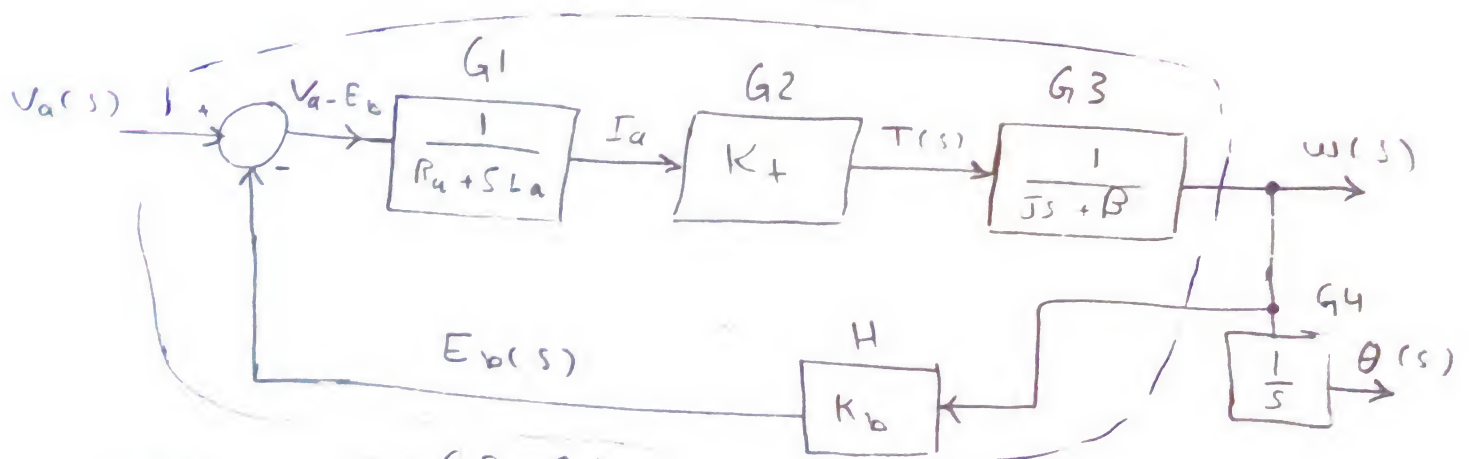
$$V_a(s) - E_b(s) = (R_a + L_a s) I_a(s) \quad (1')$$

$$E_b(s) = k_b \omega(s) \quad (2')$$

$$(sJ + B) \omega(s) = T(s) \quad (3')$$

$$T(s) = k_t I_a(s) \quad (4')$$

$$\omega(s) = s \theta(s) \quad (5')$$



$$\frac{\omega(s)}{V_a(s)} = \frac{G_1 G_2 G_3}{1 + H G_1 G_2 G_3}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{G_1 G_2 G_3}{1 + H G_1 G_2 G_3} * G_4 \quad (1)$$

$$G_1 = \frac{1}{L_a s + R_a}, \quad G_3 = \frac{1}{J s + B}$$

$$G_2 = K_t, \quad G_4 = \frac{1}{s}$$

$$1-1 = K_b$$

$$G_1 G_2 G_3 = \frac{K_t}{(L_a s + R_a)(J s + B)}$$

TF for w(s) output

$$\frac{w(s)}{V_a(s)} = \frac{K_t}{(L_a s + R_a)(J s + B) + K_t K_b}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{w(s)}{V_a(s)} \times \frac{1}{s} = \frac{K_t}{s(L_a s + R_a)(J s + B) + s K_t K_b}$$

$$R_a = 1 \Omega, \quad L_a = 1 \text{ mH} \xrightarrow{K_t}, \quad K_m = 10 \xrightarrow{K_b}, \quad K_b = 0.1 \text{ V s/m}$$

$$B = 0.5 \xrightarrow{N/s}, \quad J = 2 (K_g \text{ m})$$

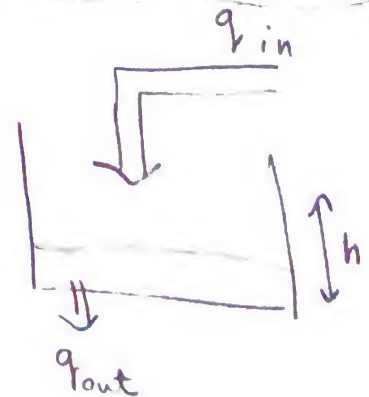
Task \Rightarrow input T load change B. Diagram

follow rate $q = \text{m}^3/\text{s}$

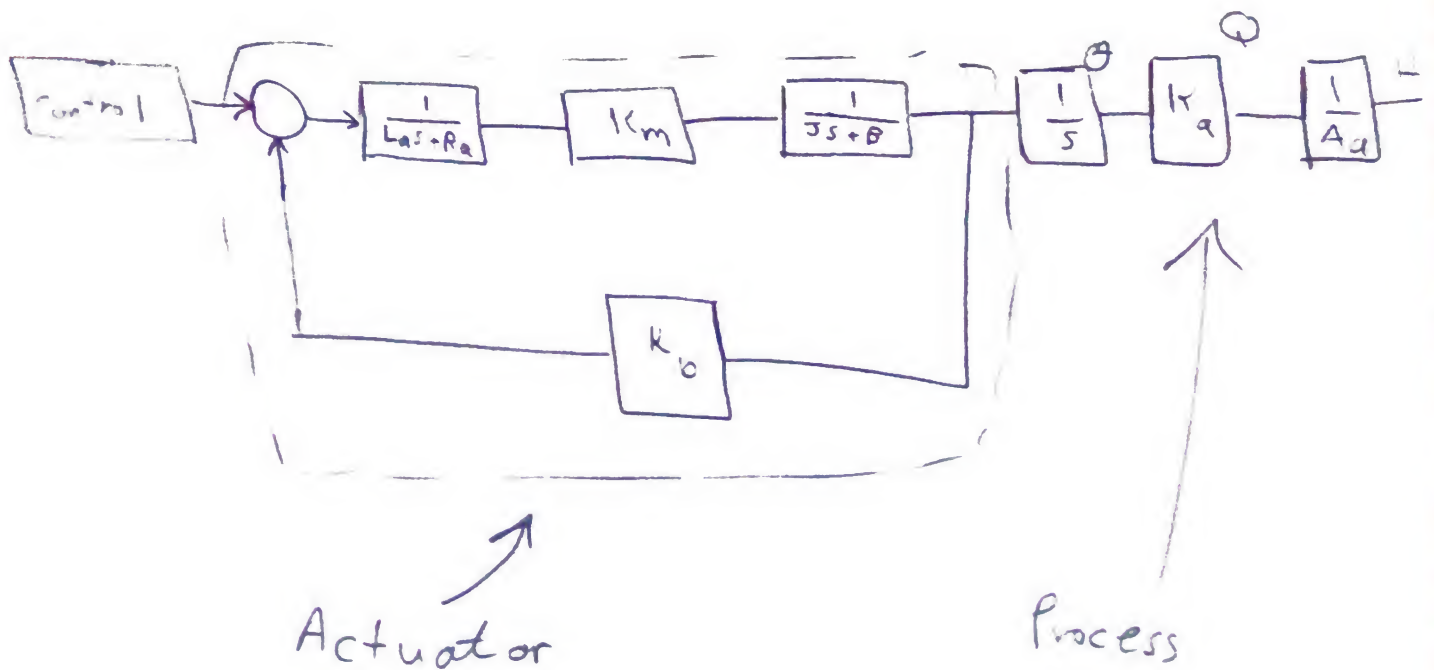
$$q_{in} = \frac{dh(t)}{dt} \times A$$

$$q_{in}(s) = s H(s) \times A$$

$$\frac{H(s)}{q_{in}(s)} = \frac{1}{A s}$$



(2)



Task \Rightarrow add T_{load} to the motor
and resketch the block diagram

Hint: θ ت عرنة ال T_{load} بتغير القيار من θ وتكون